Norwegian University
of Life Sciences

Master's Thesis 2023 30 ECTS
School of Economics and Business

Socioeconomic Impact of Changed Diet and Consequences for Norway's Agriculture

Joy Ama Betta
Applied Economics and Sustainability

Abstract

This thesis examines the socioeconomic impact of a changed diet and its consequences for Norway's agriculture. The main objectives of this research are to assess the health benefits to society resulting from the adoption of the Norwegian Dietary Guidelines (NDG) and to analyze how this dietary shift affects the agricultural sector in Norway. The study utilizes data from the Global Burden of Disease (GBD) on Disability-Adjusted Life Years (DALYs) associated with dietary risk factors such as low intake of fruits, vegetables, whole grains, fish (Omega-3), and high intake of red meat. Additionally, the NORKOST 3 survey data was employed to compare individuals' current dietary patterns with the recommended diet outlined in the NDG. Using linear optimization techniques, three models were developed to determine the optimal quantities of the maximum diet compared to the current consumption (TMREL), the current consumption and the consumption according to the Norwegian Dietary Guidelines.

The key findings reveal that switching to the diet recommended by the NDG brings economic benefits to society, as evidenced by an increase in overall utility. Moreover, adhering to the NDG leads to a freeing up of land space that can be used for cultivating more crop products instead of animal feed. These findings have significant implications, enabling households to make informed dietary decisions, informing health institutions about the role they play, and increasing awareness of the benefits associated with aligning diets with dietary recommendations.

Overall, this research contributes to the field of study by providing insights into the socioeconomic impact of dietary changes and the implications for agriculture. It highlights the potential economic benefits to society, the potential for more sustainable land use, and the importance of promoting and adopting dietary recommendations for improved public health and agricultural practices.

Acknowledgment

I am deeply thankful to God for providing me with the strength and perseverance to accomplish this milestone.

My appreciation goes to my supervisor, Eirik Romstad for his support. I am grateful to Klaus Mittenzwei, my co-supervisor for his assistance and constant feedback.

Special thanks to Ruralis for providing me with the necessary resources and a conducive office space that greatly facilitated my writing process.

To my family and my fiancé, thank you for your constant encouragement and support.

Also, to my flatmates for their support.

Ås, 15th of June 2023

Joy Ama Betta

Table of Contents

List of figures

List of tables

1. Introduction

A study conducted by the Norwegian Directorate of Health (NDH) has found that adhering to the official dietary and nutritional recommendations can lead to a range of benefits for society, including longer and healthier lives, reduced healthcare costs, increased labour productivity due to fewer cases of sickness and disability, and fewer premature deaths (Sælensminde et al., 2016). The goal of these measures has been to enhance welfare in our society by promoting healthy and enjoyable meals which is expected to improve public health (Regjeringen, 2017). Norway aims to become one of the countries in the world with the highest life expectancy and to reduce social inequalities in health. However, it has been identified that a large share of Norway's population still consumes low amounts of vegetables, fruits, fish, and whole-grain foods, while consuming high amounts of saturated fat, sugar, and salt, putting them at risk of malnutrition and undernutrition (Regjeringen, 2017).

Norway has a long tradition of meat consumption, which is primarily attributed to the perceived good taste of meat, eating habits, and dietary traditions (OECD, 2021). Becker et al. (2014) believe the Nordic Nutritional Recommendation (NNR) is a key resource for the development of food, nutrition, and health policies, as well as for creating food-based dietary guidelines and diet-related activities and programs. This serves as a basis for the development of national and regional nutrition policies, nutritional education programs, food regulations, and action programs. Since its inception in 1980, the NNR has continued to evolve over time with new updates every eight years (Fogelholm, 2013). The edition from 2004, for instance, was modified to include physical activities. According to Gustavsen and Rickertsen (2013), the dietary impacts not only relate to our health but also on the environment as about 19-29% of greenhouse gas emissions arise from agricultural activities.

Sælensminde et al. (2016) found that social benefits of following the dietary advice of the Norwegian Directorate of Health would improve public health compared to the current diet. This includes having healthy and longer years of living, reduced health service costs and an increase in labour productivity because of less sickness, disability, and death. According to the Norwegian Directorate of Health, the expected benefits to society will be even higher from the updated 2023 health recommendations (Directorate of Health, 2023b).

Becker et al. (2004) highlighted the focus of the current 5th edition on the role of dietary patterns and food groups in preventing diet-related chronic diseases, and it is intended for the general population. However, it does not apply to individuals with medical conditions or special dietary needs and does not address weight loss or sustainable weight maintenance through diet.

Norway has a relatively small farm size on average due to the Concession, Inheritance, and Allodial Act, with rented lands increasing acreage farmed by single farm operations (OECD, 2021). Meat production is more favourable than crop production due to the climate conditions that make the growing season short (Karlsson and Hovelsrud, 2021), and the complex landscape conditions characterized with mountains, fjords, lakes, and forest (Flaten and Hisano, 2007).

Norway's agriculture policy limits food imports to prevent competition with domestic production, but if demand exceeds domestic production, imports will occur (OECD, 2021). This policy results in limited product variety compared to other Nordic countries with fewer import restrictions (Janowska-Miasik, 2021), raising questions about achieving dietary recommendations substituting some meats with vegetables.

Although the market for primary agricultural products is highly regulated, Norway remains still integrated into the global value chain, exporting mostly fish and being a net importer of agro-food products (OECD, 2021). The trade barriers intended to increase agricultural production internally to achieve food security and sustainability, but this has led to market distortions (OECD, 2021). My study aims to evaluate the potential impact of a shift towards a healthier diet with reduced meat consumption on Norway's agriculture and to assess the socioeconomic benefits society has from adhering to the proposed changes in the nutritional recommendations.

1.1 Research Question and Hypotheses

Food consumption decisions of people are mostly affected by taste and convenience primarily before health, and price, and then the perception of sustainability, the impact of meat consumption on the environment is underestimated by many (Ueland et al., 2022). The goals of the Norwegian Government's Action Plan on Nutrition 2007–2011 include changing people's diets, in accordance with the recommendations by the health authorities and reducing social dietary inequalities (Directorate of Health, 2011).

The scarcity of resources in the health sector has necessitated prioritization in decision-making regarding how much to spend, and economic valuation plays a crucial role in determining the amount that can be allocated to life and health for efficient resource allocation (Elvik, 2005). Gyles et al. (2010) use the cost of illness analysis to measure both the direct and indirect cost of disease intervention to provide an estimate of how much would have been saved when a disease is prevented. Economic valuation plays a crucial role in determining the allocation of resources for life and health to make effective decisions in areas such as road safety, education, and the health sector (Elvik, 2005).

The first research question employs methods that measure the potential economic benefit to society given the nutritional recommendation. It adds to the ongoing debate on the financial appreciation of life and health, while some have argued that life has infinite value and cannot be exchanged for while others also suggest that there needs to be a limit on resource use in the health sector.

Research Question 1: What are the economic benefits to society of adhering to the Norwegian Dietary Guidelines?

The geography and weather condition of Norway may not make it conducive for large increases crop production. Many countries may already experience increases in demand for plant-based protein diets as alternatives to meat, driven by concerns for the environment and health-related issues (Hadjikakou and Paraskevas (2020). According to Jane et al. (2016), the global demand for animal protein is expected to increase by more than 20% by 2030. It is recommended that adults consume 0.8g/kg body weight of protein, which is approximately 10% of their daily energy intake. Animal proteins are known to be the best source of protein (Willet et al., 2019), and a reduction of red meat intake is likely to reduce the required protein intake. Norway needs to position itself to meet this demand by developing relevant knowledge, as meeting this demand can benefit both public health and the environment. In the next research question, the impacts of a dietary shift on Norway's agriculture are analyzed.

Research Question 2: What are the potential consequences for Norwegian agriculture if the entire population adheres to the Norwegian Dietary Guidelines?

1.2 Aim and Organization of the Thesis

The primary objective of this thesis is to assess the effectiveness of introducing nutritional recommendations in improving social welfare. This thesis aims to investigate the economic benefits that consumers can obtain by shifting from a traditional diet with high meat intake to a recommended diet consisting of more fruits and vegetables with less meat. Additionally, a decline in the consumption of red meat can affect the agriculture sector of Norway. This thesis also examines the potential consequences of a reduced meat diet on meat production by Norwegian farmers.

The first chapter of the thesis provides a general overview of the study, reviews existing literature, and defines the research problem. In Chapter 2, relevant theories are discussed, Chapter 3 describes the methods employed in the study, while Chapter 4 presents data and the results. Finally, Chapter 5 offers a comprehensive discussion, conclusion, and policy recommendations.

2. Background

2.1 The Nordic Nutritional Recommendation (NNR)

The NNR (Nordic Nutrition Recommendations) is a set of dietary guidelines that specify the recommended daily intake of essential nutrients for Nordic countries (Nordic Council of Ministers, 2012). The NNR allows for some flexibility, and its requirements can be tailored based on the requirements of a country's dietary preferences or adopted without modification. The NNR 2022 will also include environmental sustainability aspects in line with the recommendations of the Nordic Council of Ministers (Directorate of Health, 2023a). In the NNR, a set of dietary reference values expressed as daily intakes and the intake range for macronutrients, are assigned to essential nutrients. These values include the average requirement (AR), the recommended intake (RI), the upper intake level (UL) and the lower intake level (LI), and reference values for energy (Nordic Council of Ministers, 2012).

The AR in the NNR represents the nutrient intake level that is deemed sufficient to meet the needs of half of a specific group of individuals, assuming a normal distribution of those requirements (Nordic Council of Ministers, 2012). It is used to determine the RI, which is the number of nutrients considered adequate to maintain good nutritional health of healthy individuals within a particular age or gender group. The AR focuses on meeting the needs of half the group, while the RI aims to cover the needs of most people in that group (Nordic Council of Ministers, 2012). For some nutrients, values for the ARs and RIs are derived from data on the maintenance of body stores and function, along with a safety factor, but in other nutrients, the RIs are determined based on the relationship between dietary intake and chronic disease risk, as seen in experimental and observational studies.

Consuming nutrients in excessively high or low amounts can have adverse effects on health. The UL (upper intake level) represents the maximum safe amount of a nutrient that can be consumed daily without experiencing adverse effects over a long period. On the other hand, the LI (lower intake level) is the minimum amount of a nutrient needed to prevent deficiency symptoms in most individuals. Both the UL and LI are established based on factors such as age, sex, and individual characteristics to ensure that nutrient intake is within a safe and optimal range (Nordic Council of Ministers, 2012).

The concept of having a recommended diet started in the 1920s and 1930s, with the first international table of energy and protein requirements being published in 1936 by the League of Nations (Nordic Council of Ministers, 2012). The NNR was first released in 1968 by medical organizations in Denmark, Finland, Norway, and Sweden to provide guidelines for nutrient intake as part of a balanced diet, with a focus on the overall composition of the diet including fat, carbohydrates, and protein. This was due to the similarities in diet-related diseases in the region, such as heart disease, obesity, osteoporosis, and diabetes (Nordic Council of Ministers, 2012). The NNR are considered optimal because they are based on the available food composition and typical patterns of food and food group consumption. It is still unclear if there is a link between food consumption and risk, but the guidelines provide a comprehensive evaluation of the existing scientific evidence.

Physical activity guidelines included in the NNR also recommend an "active lifestyle", these are important for growth, development, and overall health and interact with food intake and dietary patterns.

2.2 Norwegian Dietary Guidelines (NDG)

The NDG developed by the Norwegian Council for Nutrition and the Norwegian Council for Physical Health serve as a basis for planning healthy diet that meets the body's nutritional requirements, supports growth and function, promotes overall good health, and reduces the risk of diet-related diseases. These guidelines are aimed at reducing the incidence of diseases and mortality caused by improper diet among the healthy and physically active adults (Directorate of Health, 2011). Research that forms the knowledge base of the dietary guidelines are mainly carried out on adults with a normal level of physical activity and can be adjusted to various population groups, including children, young people, pregnant and lactating mothers, the elderly, and individuals with various health conditions (Directorate of Health, 2011).

The first NDG focused on school children's diet and has since evolved to reduce the risk of chronic diseases like cardiovascular diseases, cancer, and osteoporosis (World Health Organization, 2003). Initially, the dietary guideline did not come with numerical recommendations to avoid distorting household consumption patterns, but this was changed when the 5-a-day recommendation came out by the National Council for Nutrition in 1996 (Directorate of Health, 2011).

The advice includes 13 diet and physical activities guidelines which can be incorporated as part of the individual's main diet. Table 2.1 shows a summary of the recommended diets:

Table 2.1: Summary of dietary advice

Advice 1	Recommended to eat a plant-based diet that contains a lot of vegetables, fruit, berries, whole grains, and fish, and limited amounts of red meat, salt, added sugar, and energy-rich foods.
Advice 2	Maintain a balance between energy intake and energy consumption.
Advice 3	Eat at least 5 portions of vegetables, fruit, and berries every day.
Advice 4	Eat at least 4 portions of whole grain products every day.
Advice 5	Eat fish equivalent to 2-3 dinner portions a week.
Advice 6	Low-fat dairy products are recommended to be included in the daily diet.
Advice 7	Lean meat and lean meat products are recommended, with a limit on the intake of red meat and processed meat.
Advice 8	When cooking, it is recommended to choose cooking oils, liquid margarine, or soft margarine.
Advice 9	Water is recommended as a drink.
Advice 10	Limit the intake of added sugar.
Advice 11	Limit the intake of salt.
Advice 12	Dietary supplements may be necessary to ensure nutrient intake for some groups in the population.
Advice 13	It is recommended that everyone is physically active for at least 30 minutes every day.

(Source: Directorate of Health, 2011)

From the table above, advice 1 and 2 are the overall assessment of diet and physical activity while advice 3 to 13 specifically relate to the food groups, dietary supplements, and physical activities. A more detailed description of the recommended intake of each food item can be found in Appendix 1.

2.3 State of Norway's Agriculture

Between 2001 and 2016, the agricultural area in Norway decreased by 17 percent from the peak year of 2001 to 2018. The OECD sets the average agricultural land as a percentage of a country's surface area at 34%. Norway's total surface area is 324,000 km², with only 3% designated for agriculture, and only 88% of this area is currently in use. The largest portion of the total surface area, 38%, is covered by open ground. Grain production is channelled to the area that has better-growing condition and easy access to non-farming equipment while animal husbandry is done in areas with unfavorable conditions (OECD, 2021).

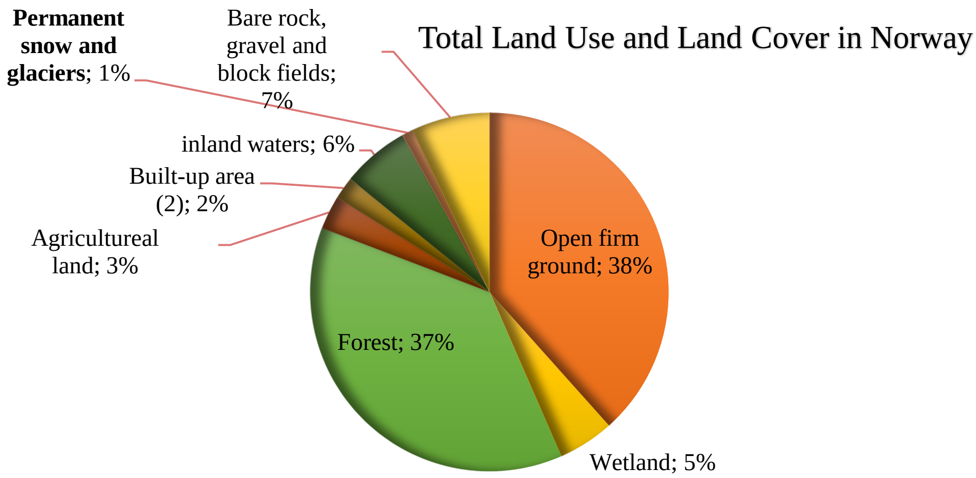

Figure 2.1: Total land use and land cover in Norway 2018 (Source: OECD, 2021)

Grazing supports account for about 1 billion NOK and covers approximately 50% of the coarse animal feed used for Norwegian meat production annually, this helps maintain the open landscape and imparts a unique taste to the meat of the animals (Knutsen, 2022).

The annual total income from gross output in the agriculture sector thus varies depending on weather and market conditions, as well as changes in price and support policies (Knutsen, 2022). From Figure 2.2 below, it can be observed that the largest share of the income is generated from meat production, which accounts for approximately 39.2% of the total revenue. Milk production is the next highest revenue source, accounting for about 28.9%.

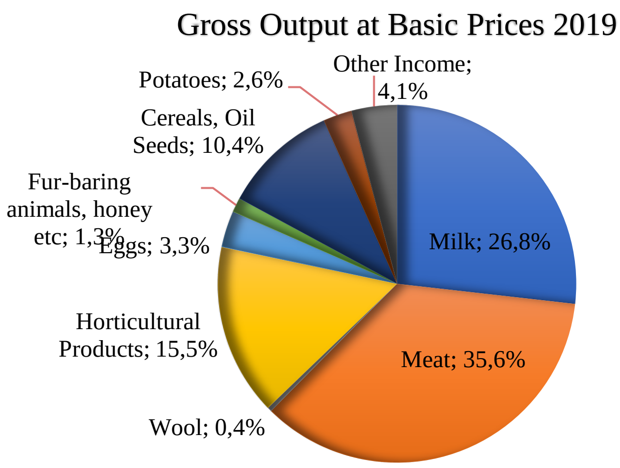

Figure 2.2 Gross output at basic prices by commodities 2019, expected value. (Source: Budsjettnemnda for jordbruket (2019)

2.4 Norway's Agricultural Policy

The Ministry of agriculture oversees providing agricultural related policies in Norway which relates to agricultural production, food and management, the entire food chain. To design the agricultural policies, the government works hand in hand with the National Farmers Organizations Small Holders Union (Norsk Bonde-og Smabrukarlag), which is the Norwegian Farmer's union (Norges Bondelag) and the Norwegian Farmer's and Smallholders together with the Ministry of Trade, Ministry of Industry and Fisheries and the Ministry of Health and Care Services (OECD, 2021).

The primary goal of Norwegian agricultural policy is to provide support to the agricultural industry and its value chain while promoting the sustainable production of nutritious and high-quality products (OECD, 2021). It is structured on four pillars: border protection, legal framework, annual negotiations and agreements, strong boarder protection, farmers' responsibility for marketing balance through producer cooperatives, and a property policy to secure family-owned farms (OECD, 2021).

The policy programs also include the setting of target prices, agricultural policy programs like direct support schemes and welfare support programs, market regulation systems that includes the levies paid my producers and any other quotas set. The annual regulations have been in place since 1950 and are set for the net farm incomes so farming can be maintained (OECD, 2021).

The most extensive and significant economic and trade agreement for Norway is the European Economic Area Agreement between the EU and Norway, Iceland and Liechtenstein in 1994. The agreement create a single market with free movement of goods, services, person and capital as well as non discrimination and equal rules of competition. To regulate and stabilize domestic prices, the Marketing Act (Omsetningsloven) of 1936 strengthens Norway’s border protection measures and domestic market regulations (OECD, 2021). The act is what regulates the domestic market for specific agricultural products such as meats, dairy, crops, and fruits and is administered by The Sales and Marketing Council (Omsetningsrådet). Key regulatory measures include production and demand forecasts, marketing, storage, and some exports. It's worth noting that subsidized exports were abolished starting from January 1, 2021 (OECD, 2021).

Certain products, such as rice, cotton, bananas, citrus fruits, coffee etc, that cannot be grown in Norway, and are not subject to import tariffs while other products are automatically reduced for a short period when domestic prices exceed threshold levels for two consecutive weeks (OECD, 2021). For domestic market balance for various commodities, export subsidiescan be adjusted by producers based on the expected surplus. In the dairy sector for instance, , production control measures such as the milk quota system have effectively reduced these surpluses (OECD, 2021).

Another common practice in Norway is the establishment of agricultural producer co-operative that forms the federation of Norwegian Agriculture co-operatives (Norsk Landbrukssamvirke). The are 16 nationwide co-operative organizations in Norway that play a role in sales, purchasing, or breeding. The three largest producer co-operatives are Tine SA (dairy), Nortura (meat and eggs), and Norske Felleskjøp BA (grains) (Figure 2.3). Tine and Nortura act as sole regulators in their respective sectors, while Norske Felleskjøp may engage in market regulation with other grain traders through a tender process (OECD, 2021).

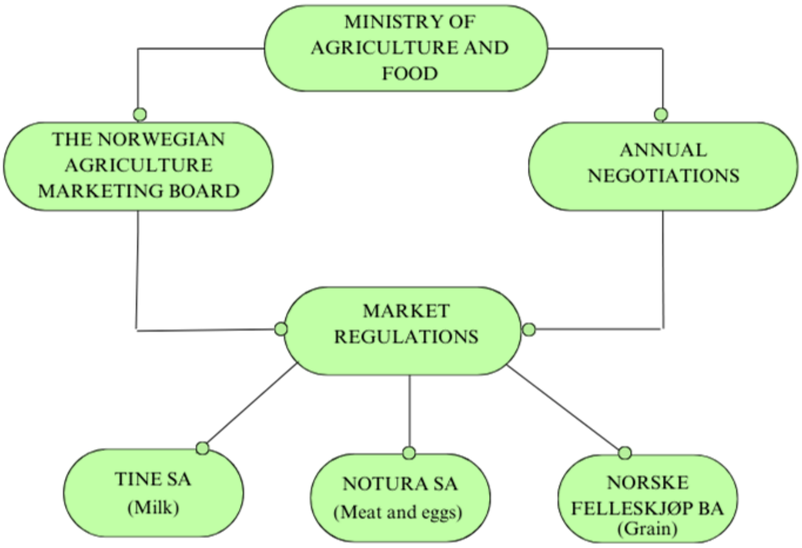

Figure 2.3 Agricultural policy framework in Norway. Source: OECD (2021)

2.5 Existing Literature on the Agricultural Policy and Tariffs

Friel et al. (2020) argued that trade agreements can hinder efforts against malnutrition and climate change. They highlighted how trade agreements can affect the government's ability to create food systems that prioritize nutrition and climate goals, including marketing barrier removal for agricultural commodities and protecting regulatory policy. Moreover, they emphasized the importance of coherence between trade-policy goals and public-interest goals, such as nutrition and climate change, which involve actors' interests, ideas, and formal and informal institutional processes at various levels.

Mittenzwei et al. (2020) estimated changes in greenhouse gas emissions from substituting meat with vegetable intake. They emphasized the importance of including socioeconomic analysis in such studies, as different socioeconomic factors can impact dietary choices. However, they faced challenges in specifying diets low in red meat but high in fish and vegetables, as such diets can be defined in different ways. They used NIBIO's diet scenarios to assess the impact of diets on greenhouse gas emissions and found that compliance with dietary guidelines is necessary to achieve climate and environment goals. They defined red meat as the sum of cattle, sheep/lamb, and pig, and based dietary advice on individual food intake.

Abadie et al. (2019) studied the impacts of food taxes and subsidies in achieving emission reduction targets. Their study highlighted how food consumption affects both health and the environment, with animal products, particularly meat from ruminants, emitting greenhouse gases and requiring more land and water use. They were studying the increasing demand for meat and the challenge of feeding the growing population while promoting a balanced diet. They emphasized the effectiveness of policies that control the amount of food production rather than those controlling consumption, cautioning that supply-side policies aimed at increasing production could lead to an increase in consumption and uncertain effects on GHG emissions.

Consequently, policies aimed at reducing GHG emissions in the agriculture sector should focus on controlling the amount of food production rather than consumption.

An earlier study by Abadie et al. (2016) uses data from the yearly Norwegian Consumer Expenditure Survey (CES) conducted by Statistics Norway to perform an optimization analysis. 100-1500 participants were required to keep track of their consumption for a 2-week period. However, this data is not as accurate as the individual-level data from Norkost 3, a survey on food intake, conducted by the University of Oslo, the Norwegian Health Directorate, and the Norwegian Food Safety Authority between 2010 and 2011. A potential weakness of the Norkost 3 data is a lack of information on micronutrients and expenses collected over several years. The data showed a disparity with the recommended diet by the health authorities. The Norwegian Consumer Expenditure Survey between 1986 to 2012 was used to calculate the price elasticity of demand and expenditure elasticity using a 2-stage demand system with the Almost Ideal Demand System (LA/AIDS). To calculate the elasticities, that study used the average quantities consumed per day and provided details on the macronutrients. Its main finding was that a few changes in diets can result in limited yet useful emission reduction targets.

Irz et al. (2015) provided an easy understanding of the likely effects of complying with a nutritional recommendation. They derive dietary adjustments from consumers based in the information from consumption preferences. A calibration exercise was used to smooth how different income groups based on the French diet will adjust to a nutritional recommendation which will translate to a health outcome. Various nutritional factors have been linked to chronic diseases such as obesity, stroke, diabetes, and certain cancers raising concerns about the risks associated with these factors. According to Irz et al. (2015) the nutritional recommendation comes in different forms. Different strategies have been implemented to promote these recommendations to many people especially those who are perceived to be at risk. It has been widely shown that adopting a new nutritional recommendation is challenging and does not result in any change in behaviour.

Meunier’s (2019) study builds on the work of Irz et al. (2015). Here, the health consideration factor was incorporated into the model while assuming a behaviourally biased consumer. This helped in reducing the number of health benefits already internalized by the consumer. When consumers make food choices, they often do not fully consider the health impact of their choices. If individuals were to consider health factors in their decision-making, the overall benefit derived from following nutritional recommendations would likely be reduced. This observation remains true even when an individual's diet is influenced by information campaigns. However, if individuals are influenced by such campaigns, their taste preferences (taste cost) as calculated by Irz et al. (2015) may be adjusted to reflect the impact of the information on their choices. As they become more aware of the positive effects of a healthier diet and experience the benefits, their preferences and decision-making can shift towards incorporating health factors into their utility function. In this way, aligning their food choices with nutritional recommendations can lead to improved utility and overall well-being.

2.6 Hypotheses

Hypothesis 1: There are health benefits to society if they adhere to the Nordic Dietary Guidelines.

Following the recommended Nordic Dietary Guidelines (NDG) is believed to produce positive health benefits. The diet encourages a balanced diet that is high in fruits, vegetables, and whole grains while limiting intake of processed foods and added sugars. By making changes to their diets in accordance with these guidelines, individuals may experience improvements in their overall health and wellbeing, as well as a reduction in the overall burden of disease which is measured in DALYs (Disability-Adjusted Life Years).

Hypothesis 2: The decreased demand for red meat will cause substantial agricultural shifts if the entire population in Norway adheres to the NDG.

Adhering to the NDG emphasizes the consumption of fruits, vegetables, and plant-based foods, leading to a potential reduction in the demand for red meat. This shift in dietary preferences could result in a reallocation of land resources. Land that was previously dedicated to livestock farming or growing feed crops for animals could be repurposed for cultivating crops intended for human consumption. The increased demand for fruits, vegetables, and other plant-based foods would necessitate more land for their cultivation to meet the growing needs of the population following the NDG.

3 Theory

3.1 Introduction

These chapter examines the theoretical foundation for understanding individuals' choices in food consumption, evaluating societal impacts, and quantifying the economic value attributed to health improvements.

3.2 Consumer Theory

By rule, an individual will demand more of a commodity where the price of the commodity falls. The simple relationship of quantity demanded, and quantity supplied for a product and the different factors influencing this is represented by a downward-sloping demand curve and an upward sloping supply curve (Andreosso-O'Callaghan, 2003)

The analysis of consumer demand plays a crucial role in developing effective food policies (Okrent and Alston, 2012). Consumer demands can be estimated using either an unconditional or conditional demand system. Conditional demand system focuses on the interdependence within a group of substitute products, ignoring substitution outside the group while an unconditional demand system considers interdependence among closely related food or non-food groups (Okrent and Alston, 2012). One way to measure consumer demand is through elasticities, which include the own-price elasticity of demand, cross-price elasticity of demand, and expenditure elasticity of demand (Okrent and Alston, 2012). The own-price elasticity of demand measures the responsiveness of demand for a specific product to changes in its own price. The cross-price elasticity of demand measures the responsiveness of demand for one product to changes in the price of another product. Lastly, expenditure elasticity of demand examines the responsiveness of demand to changes in income or expenditure level (Okrent and Alston, 2012).

Consumer theory assesses the process of decision-making of a rational consumer in relation to their consumption. It helps in understanding how consumers allocate their resources and make consumption decisions, based on the assumption that consumer choices are determined by prices and income (Levin and Milgrom, 2004).

The consumer problem can be mathematically represented as follows:

$$\max_{x \in \mathbb{R}_+^n} u(x)$$
$$s.t.\ p\,.\,x\ \leq w$$

According to Levin and Milgrom (2004), the problem assumes that the consumer selects a vector of goods $x = (x_I, \ldots, x_n)$ to maximize his or her utility while respecting a budget constraint that total expenditure $(p.x)$ cannot exceed total wealth (w) The variable x represents quantities of different goods at a specific moment or the average rates of consumption over time.

The consumer's set of choices, represented by the budget set, is denoted as:

$B(p, w) = \{x \in \mathbb{R}_+^n : p.x\ \leq w\}$

The consumer's objective is to select the vector $x \in B(p, w)$ that is most preferred or, equivalently, has the highest utility (Levin and Milgrom, 2004).

Considering only two goods, the budget set can be graphically represented in the figure 3-1 below.

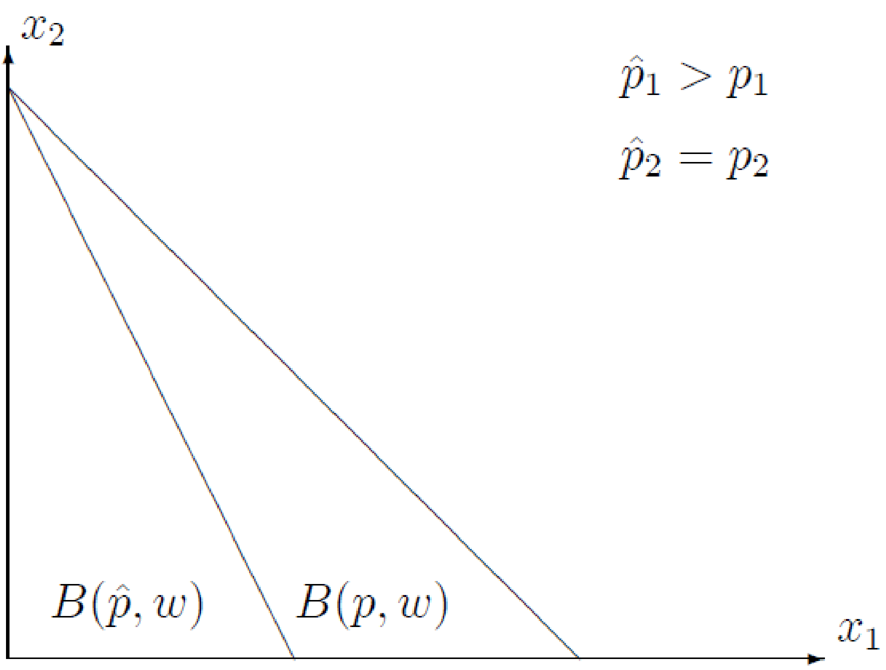

Figure 3-1: The budget set at different prices. (Levin and Milgrom, 2004)

The model is based on the assumptions that:

1. The consumer is assumed to have perfect information about the products being considered.
2. The consumer takes prices as given and does not engage in activities such as searching for better prices or bargaining for discounts.
3. Prices for goods are linear, meaning the price per unit of a particular good is constant.
4. Goods are considered divisible, allowing the consumer to purchase any amount they can afford, even though the model can still accommodate situations with discrete, indivisible goods.

3.3 Lancaster's theory on budget shares for groups of consumer goods

The Lancaster (1966) model introduces an approach to analysing consumer demand by focusing on the characteristics of goods rather than the goods themselves. In this model, goods or collections of goods are treated as consumption activities, each associated with a scalar value representing the level of activity (k).

The relationship between the level of activity and the goods consumed is assumed to be linear represented by equation 1:

$$x_j = \sum_k a_{jk} y_k \dots \dots \dots \dots \dots \dots \dots \dots (1)$$

x_j represents the jth commodity consumed, and it is equal to the product of a coefficient (a_{jk}) and the level of activity (y_k). To represent the total goods required for a given combination of activities, we introduce a vector (x) which is obtained by multiplying a coefficient matrix or the product of coefficients (A) with the activity vector (y) as in equation 2 below.

$$x = Ay \dots \dots \dots \dots \dots \dots \dots \dots (2)$$

Furthermore, each consumption activity is assumed to produce a fixed vector of characteristics (z_i).

$$z_i = \sum_k b_{ik} y_k \dots \dots \dots \dots \dots \dots \dots \dots (3)$$

Equation 3 implies that when engaging in a specific activity denoted by the level of activity (k), a set of characteristics (z_i) is generated. Additionally, the relationship between the vector of characteristics (z_i) and the activity vector (y) is represented in Equation 4.

$$z = By \dots \dots \dots \dots \dots \dots \dots \dots (4)$$

The individual is assumed to possess an ordinal utility function on the characteristics, denoted as U(z), and that the individual will choose a situation that maximizes their utility function.

The utility function U(z) is provisionally assumed to possess the ordinary convexity properties of a standard utility function. The goal is to:

$$Maximize\ U(z)$$
$$\text{Subject to } px \ \leq k$$

With;

$$s \ = By$$
$$x \ = Ay$$

Using the idea from the Lancaster (1966) model, Chernichovsky et al. (1997) specify the intake of a nutrient model as follows:

$$A_j = \sum_{i=I}^{n} t_{ij} X_i \ , \ldots\ldots\ldots\ldots (2)$$

where the intake of nutrient j is expressed as a linear function of n food items $X_{i,}$ consumed. A_j is the total intake of nutrient *j* and t_{ij} is the amount of nutrient j contained in food item *Xi*. The model allows for the substitution of A_j to get *m* inequalities for *m* nutrients, B_j is introduced into the model as the minimum requirement of nutrient *j*:

$$\sum_{i=I}^{n} t_{ij} X_i \ \geq \ B_j, \ldots\ldots\ldots\ldots (2)$$

$$X_I = x_I\left(I_j, P_I, \ldots, P_{n+1}\right) \ldots\ldots\ldots\ldots (3)$$

Chernichovsky et al. (1997) defines X_{n+1} as a composite good for all items which are non-food.

The initial model was expanded to give,

$$A_j \ = \ \sum_{i=I}^{n} t_{ij} X_i \left(I * j, P_i, \ldots . P_{n+1}\right) \ \geq \ B_j \ \ldots\ldots\ldots\ldots (4)$$

And is further simplified into a Cobb-Douglas type utility function:

$$X_i \ = \propto_i \ (I/P_i) \ \ldots\ldots\ldots\ldots (5)$$

The variable X_i equals the level of consumption of X_i that a given price P_i and the share of total household expenditure on food X_i. Equation (5) assumes that all demand functions have unitary price and income elasticities, and all cross-elasticities are zero. Based on this function, households can adjust their consumption levels of X_i by altering their income I, price P_i, or both. Thus, the "demand function" for each nutrient A_j becomes.

$$A_i = \ I \sum_{i=I}^{n} \propto_i \ (I/P_i) t_{ij} \ \ldots\ldots\ldots\ldots (6)$$

3.4 Welfare Theory

Contributors to welfare theory include Smith (1776), whose concept of the invisible hand provides an understanding of how self-interested investors can allocate capital optimally to industries, thereby benefiting society. Subsequently, Dupuit (1844) and Gossen (1927) developed the modern utilitarian framework in economics and Walras (1874) introduced the general equilibrium system based on utility maximization and profit maximization which many modern welfare theories relate to.

3.4.1. Welfare for a representative consumer

An advantage of Lancaster's theory of consumer demand is that it allows for the analysis and focus on a single consumer good, such as agricultural goods, by considering consumer preferences and choices within that specific domain (Lancaster, 1966). When prices or income change, consumers may experience improvements or declines in their well-being. Assuming the government aims for balanced budgets, this implies that subsidies provided to farmers necessitate increased taxes on consumers. To be indifferent between a situation with agricultural subsidies and one without, the indirect utility function is expressed as follows:

$$V_s(p_s, I \ - \ T_s) \ = \ V_o(p_o, I \ - \ T_o) \ = \ V_o(p_o, I) \ldots\ldots\ldots\ldots (1)$$

the subscript ‘s’ represents the case with agricultural subsidies, while the subscript ‘o’ represents the situation without agricultural subsidies

p = consumer prices for agricultural goods,

I = disposable income for agricultural goods.

T_O = taxes (This is assumed to be equal to zero).

These considerations are crucial for understanding the welfare implications of agricultural subsidies and their effect on the representative consumer's well-being within the Lancaster framework (Lancaster, 1966).

3.4.2 Individual consumer welfare with health benefits from a changed diet

In analyzing individual consumer welfare with health benefits derived from a changed diet, the focus can also specifically be on the impact of dietary modifications on well-being. By considering the health benefits alone, the indirect utility function in equation (1) can be modified as follows:

$$V_s(p_H^s, I - T_H^s) = V_o(p_o, I; O) \ldots\ldots\ldots\ldots (2)$$

In this revised expression, the subscript ‘H’ represents the incorporation of health benefits resulting from the dietary change, while the subscript ‘O’ indicates the absence of any change in health (representing the status quo without dietary modification).

By examining this modified indirect utility function, we can gain insights into the consumer's preferences and assess the impact of health benefits on their overall well-being. This analysis allows for the understand the welfare implications of dietary changes and their influence on individual consumer satisfaction within the context of health-related factors (Varian, 2014).

3.4.3 Welfare at the society level

To assess welfare at the societal level individual welfare for specific income groups is considered which gives equation 3:

$$W_H^i = V_i^s(P_H^s, I - T_H^s;\ H) \ldots\ldots\ldots\ldots (3)$$

where "i" indexes the income group, and W_H^i represents the welfare of the ith individual when health benefits (H) are incorporated, considering consumer prices P_H^s and disposable income $I - T_H^s$ specific to that income group.

Similarly, we have:

$$W_i^o = V_i^o(p^o, I;\ O) \ldots\ldots\ldots\ldots (4)$$

where W_i^o represents the welfare of the ith individual in the absence of health benefits (O), considering consumer prices (p^o) and disposable income (I) specific to the income group.

Social welfare can be characterized by a vector of individual welfare: (W^1, W^2, W^3,… W^i) where W^i represents the welfare or "good" of the ith individual, and i denotes the total number of individuals (Ng, 1983). Economists often subscribe to the utilitarian concept of summing individual happiness, as individuals are considered better evaluators of their own well-being. In this concept, social welfare is represented by the equation:

$$W = U^1 + U^2 + \ldots + U^i = \sum U^i \ldots\ldots\ldots\ldots (5)$$

Here, U^i is a utility index representing the preferences of individual i.

An example application of this welfare function to health involves maximizing the utility function while considering the total number of Quality-Adjusted Life Years (QALYs) gained within a budget constraint (Dolan, 1998). QALYs quantifies the number of years of life lived in good health, further elaboration on this concept will be provided later in this chapter. This approach combines individual preferences, health outcomes, and budgetary considerations to determine the optimal allocation of resources for maximizing societal welfare (Dolan, 1998).

3.5 Economic Valuation of Health

Cost-benefit analysis of an intervention is a form of economic valuation that takes a "social welfare" viewpoint, it considers all costs and benefits irrespective of who bears them (Cohen and Flood, 2022). They describe cost as all the resources that are utilized by a program, either directly or indirectly, which could have been used for other purposes while benefits are any valuable outcomes that are generated as a result.

Although measuring health is challenging (Neumann et al., 2008), many studies have been able to achieve this using various parameters like anthropometric measurements of child height-for-age or weight-for-height z-scores, blood pressure readings for adults, and Quality Adjusted Life Years (QALYs) or Disability Adjusted Life Years (DALYs), along with life expectancy or related measures (Bommier and Stecklov, 2002). The socioeconomic analysis is helpful in ranking the different measures, but it cannot value all societal effects of a measure (Mittenzwei et al., 2020). The concept of a "Value of a Statistical Life" (VSL) is used to associate a monetary value with how much everyone is willing to pay to reduce the risk of premature death based on a given policy but not the cost of the risk itself (Elvik, 2005).

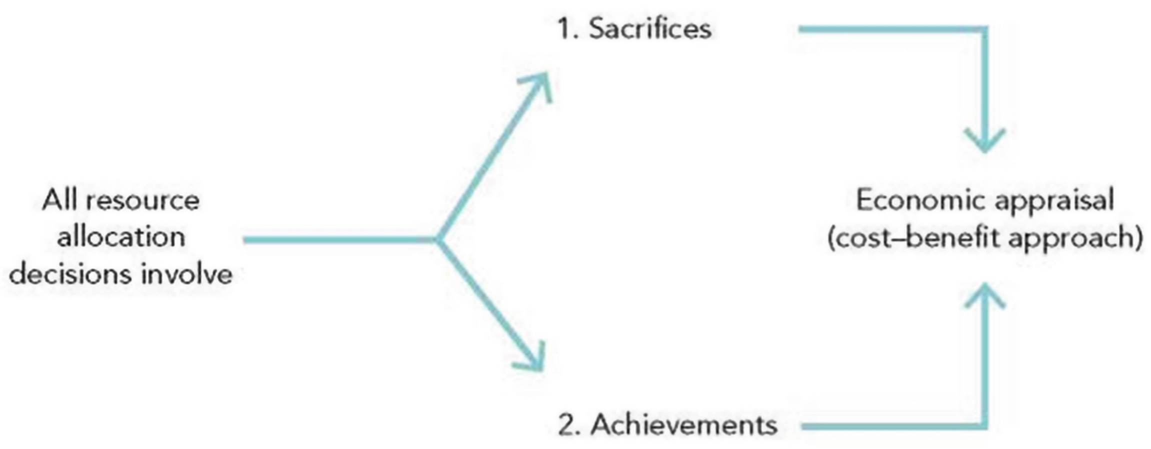

Figure 3-2 : Source: The cost–benefit framework (Cohen and Flood, 2022).

From the figure above, using the cost-benefit approach involves weighing the gains against the sacrifices, where the costs refer to the alternative that must be forgone. Cost-benefit tests are used to determine if the benefits outweigh the costs. If the costs outweigh the benefits, it means the health gains achieved are not worth the health sacrifices and are forgone by not using resources in other ways, even though the health gains may still be worth some amount of money Cohen and Flood (2022). In calculating the impact of a nutritional recommendation, DALYs and QALYs are widely recognized as useful tools for measuring the burden of disease and providing a universal assessment of mortality and morbidity (Sassi, 2006; Murray and Acharya, 1997).

3.5.1 Quality Adjusted Life Years (QALYs)

QALYs measure the number of years lived in good health (Murray and Acharya, 1997). According to Sassi (2006), QALYs of an individual lived in one year can be calculated as:

$$QALYs\ lived\ in\ one\ year = 1 * Q \quad where\ Q \leq 1$$

Q = health-related quality of life weight attached to the relevant year of life.

A further measure is to calculate the Quality-Adjusted Life Expectancy (QALE) of a person at age *a given as*:

$$QALE = \sum_{i=a}^{a+L} Q_t$$

Where:

L = residual life expectancy of the individual at age *a*,

t = individual years within that life expectancy range.

The value of t can be shorter units of time when a person is projected to have a change in the quality of their life at shorter intervals say a month in a period less than the yearly period (t),

L will have to be defined consistently. With this inclusion of time preference and discounting, the QALE equation becomes:

$$Discounted\ QALE = \sum_{t=a}^{a+L} \frac{Q_t}{(1+r)^{1-a}}$$

From the equation:

r is defined as the discount rate.

When they are applied in economic valuation or health as stated earlier, QALYs are primarily used in cost-effectiveness analysis to determine the improvement in quality-adjusted life expectancy achieved by a specific health intervention. In such a case, the quantity of QALYs acquired can be calculated as follows:

$$QALYs\ gained = \sum_{t=a}^{a+L^i} \frac{Q_t^i}{(1+r)^{1-a}} - \sum_{i=a}^{a+L} \frac{Q_t}{(1+r)^{1-a}}$$

From the equation:

Q^i is a vector comprising quality of life weights associated with health predicted or observed during each period t after the intervention.

L is the duration of the disease, while the period over which an individual enjoys the benefits of treatment is L^i which may be longer than L when treatment extends life expectancy or when treatment affects the quality of life for a longer period.

3.5.2 Disability Adjusted Life Years (DALYs)

DALYs is a measure that combines the years of life lost (YLL) and the healthy life lost (YLD) because of disability, illness, or disease. Years of life lost is the difference between the age a person dies and the age the person is expected to die. YLD on the other hand is determined by multiplying the number the number of non-fatal incident for specific diseases or injuries by the average duration of disability that is associated with each event (McKenna et al., 2005).

The concept of DALYs emerged in the early 1990s, based upon the idea of Quality-Adjusted Life Years (QALYs). It is a measure of the disease burden used widely in cost-effectiveness analysis and was developed based on the idea of QALYs (Murray and Acharya, 1997). This method of economic valuation incorporates an age weighting function by assigning different weights to life years and different age levels (Sassi, 2006) with a standard maximum life expectancy of 80 years for men and 82.5 years for women (Anand and Hanson, 1997).

Murray and Acharya (1997) set two principles that establish functional forms and provide grounds for DALYs. First, the calculated burden for similar health outcomes should be the same meaning every health outcome can be categorized by various variables which include the specific health outcome and individual properties such as age, income, and preferences. Second, the basis for the calculation of the associated burden of disease, requires that the non-health characteristics of the individual affected by a health outcome be constrained to just age and sex.

In the measurement of DALYs, 0 is used to equate perfect health and 1 equates to death, this implies that, the closer the value is to 1, the more severe (Murray, 1994). The weight factors are adjusted to reflect the social preference of the individual and are discounted with time to be in favour of current benefits to future benefits (Anand and Hanson, 1997), and provide a measure which accounts for premature death, physical impairment because of illness and the duration of illness (Murray and Acharya, 1997).

DALYs can be represented with the formula below:

$$\Delta_{ij}^{t} = \int_{a_i^t}^{a_i^t + L(a_i)} KD_j Cxe^{-\beta x} e^{-r(x - a_j^t)} dx \qquad (1)$$

In equation 1, each individual is assigned a non-uniform weight, allowing for a more refined assessment of the disease burden. The variables are defined as follows:

Δ_{ij}^{t}= the DALYs for a specific individual i and sequela j at time t.

x = time variable

a_i^t= age at onset for individual i at time t

$L(a_i)$= the duration of the sequela j for individual i.

D_j= disability weight due to sequela j. This is not an absolute measure with has properties almost like an interval scale measured between 0 and 1.

C = age-weighting correction constant

β = age-weighting parameter such that the peak weight for a year of life is assigned at

age (1//3).

r = discount rate, accounting for the diminishing value of future years.

K = binary factor to adjust the age weighting parameter β

By integrating Equation 1 over the relevant time and age range, DALYs can be calculated, considering the disability weights, age-weighting factors, and discounting. The resulting equation, denoted as Equation 2, is applicable when the discount rate (r) is not equal to zero

$$DALYs[r,K] = D\{\frac{KCe^{ra}}{(r+\beta)^2}\Big[e^{-(r+\beta)(L+a)}[-(r+\beta)(L+a)-1] - e^{-(r+\beta)a}[-(r+\beta)a-1]\Big] + \frac{1-K}{r}(1-e^{-rL})\} \qquad (2)$$

When $r = 0$, the equation is denoted in equation 3:

$$DALYs[0,K] = D\{\frac{KCe^{ra}}{\beta^2}\left[e^{-(\beta L)}(-\beta(L+a)-1)-(-\beta a\ -1)\right]+(1\ -\ K)L\} \qquad (3)$$

The aggregate DALY at time t for a society with a population N, considering incidences occurring at time t, is expressed as follows

$$\Delta_t = \sum_{i=0}^{N_t} \Delta_i^t \qquad (4)$$

Equation 4 gives a framework for discounting into the future. Murray provides two arguments in discounting DALYs. First if health benefits are not discounted, then 100% of resources should be channelled to disease eradication plans that have finite costs, as this will eliminate infinite streams of undiscounted DALYs which will outweigh all other health investments that do not result in eradication. This argument according to Annad and Hanson (1997) does not provide a reason to discount DALYs and that the concern for equity should be incorporated directly in a temporally neutral way.

$$\Delta_t = \int_0^T \Delta_t\, e^{-rt}\, dt \qquad (5)$$

Within a specified planning period, the minimization of Disability-Adjusted Life Years (DALYs) will be based on Equation 5.

The impact of an intervention (B) can be determined by calculating the difference between the estimated number of DALYs that would occur in the absence of any interventions (Δ_{NOI}) and the estimated number of DALYs in the presence of the implemented intervention (Δ_{WI}). A positive value of B indicates the extent to which the policy is successful in improving health outcomes and reducing the burden of disease. This is given as:

$$B\ =\ \Delta_{NOI}\ -\ \Delta_{WI} \qquad (6)$$

3.5.3 Comparison of QALY and DALY

DALYs and QALYs are generic paradigms for setting healthcare priorities (Augustovski et al., 2018). QALYs represents a positive concept as it measures the number of years lived in good health. DALYs on the other hand is a negative concept as it measures the number of years that have been lost due to disability, illness or disease (Murray and Acharya, 1997).

Sassi (2006) provides some limitations of the two measures as one could have an advantage over the other based on the context of use.

1. The measures do not provide a comprehensive assessment of the broader effects of these interventions, including their impact on emotional and mental health, careers, and the potential economic and social consequences.
2. Preventive treatments and chronic diseases are not effectively measured by QALYs as they can lack sensitivity.
3. Calculating DALYs using standard life expectancy figures may lead to an overestimation of the amount of DALYs saved especially in cases where the actual life expectancy is shorter.
4. There are ethical concerns related to using DALYs to discount future health benefits: Are non-disabled or young adults more efficient to society? Will the value of health appreciate over time? According to Maynard (1939), it is risky to assume that a diet suitable for growth is also optimal for adult life thus the role of nutrition in the aging process should be studied independently.

Murray (1994) outlines several differences between DALYs and QALYs. These differences include:

1. DALYs incorporates an age-weighting function assigning different weights to life years lived at different ages, while the QALY does not.

2. The origins of disability and quality of life weights differ significantly between the two measures.

3. Disability profiles upon which DALY calculations are based tend to be simple, while quality-of-life profiles for QALY calculations tend to be more elaborate.

4. Calculation methods for DALYs may be relatively complicated, while the corresponding calculation methods for QALYs can be made less cumbersome by using a discrete approximation of a continuous health function.

4 Data and Methods

This chapter introduces the empirical work of this thesis, providing insights into the rationale for the choice of models, and methods used in the analysis. It includes the systematic formation, estimation, and analysis of relevant econometric models as well as the identification, selection, and processing of data. The study utilizes secondary data from online databases, past literature, and personal communications to assess the socioeconomic impact of a changed diet and the consequences on Norway's agriculture.

4.1 Data Sources

Norwegian Dietary Guidelines

The Norwegian Dietary Guidelines provide evidence-based dietary advice to the general population, drawing on knowledge from both national and international sources. These guidelines aim to promote overall health and prevent chronic diseases (Directorate of Health, 2023b). The guidelines include specific data on recommended portion sizes for various food groups, such as fruits, vegetables, whole grains, lean proteins, dairy or dairy alternatives, and healthy fats. They also provide guidelines for achieving sufficient intake of essential nutrients, including vitamins, minerals, and dietary fibre. Additionally, the guidelines offer recommendations for fluid intake and emphasize the importance of regular physical activity (Directorate of Health, 2023b).

Norkost 3 Survey

The Norkost 3 survey was carried out in 2010-2011 through a collaboration between the University of Oslo, the Norwegian Health Directorate, and the Norwegian Food Safety Authority. The survey interviewed a total of 1787 individuals, with a balanced distribution of 48% men and 52% women, ranging in age from 18 to 70 (Directorate of Health, 2012*)*. The participants were asked about their daily food intake over the past 14 days. The survey encompassed individuals born in Norway, Sweden, and Denmark (Directorate of Health, 2012).

The data was used to estimate the macronutrient content derived from different diet types consumed by the participants. This facilitated a comprehensive comparison between the actual diets of Norwegians and the recommended dietary guidelines. Additionally, the survey gathered information on the intake of various nutrients, such as vitamins, minerals, and macronutrients. It also explored the sources of food and included demographic information (Abadie et al., 2016).

Matvaretabellen (The Food Table)

This provides in-depth data on the energy and nutrient content of the everyday food eaten in Norway. The table values are updated annually and refer to the nutritional content of 100 g of edible product. They are obtained from chemical analyses performed by quality-assured Norwegian laboratories, borrowed values from industry or foreign food tables, and estimated values calculated from similar foods and dishes (Norwegian Food Safety Authority, 2022).

The project receives funding from the Norwegian Food Safety Authority and has practical work carried out by the Department of Nutritional Sciences at the University of Oslo and the Norwegian Food Safety Authority (Norwegian Food Safety Authority, 2022). Based on the recommended diet from the NDG and observed intake from the Norkost 3 survey, the macronutrients for each product are calculated and is presented in Appendix 1.

Global Burden of Disease (GBD)

The current GBD data was released in 2019 by the Institute for Health Metrics and Evaluation (IHME) in 2021. It contains estimates of the burden of diseases, injuries, and risk factors for 204 countries. The dataset includes estimates of 15 dietary risks and burdens with estimates of daily intake of diet types in grams or percent energy across different demographics (IHME, 2021). These diet types presented in the GBD are consistent with the nutritional recommendations for those diet types, as reported in Oslo Economics (2020). However, not all the dietary diet types presented in the GBD dataset are included in Oslo Economics (2020).

DALYs have been retrieved from the GBD for males and females aged 25 and above for Norway. The data on DALYs reflect the risk of dietary exposure associated with a daily intake of the selected food groups, which includes the risk associated with diets low on whole grains, fruits, vegetables, and fish, as well as the risk associated with diets high in red meat (IHME, 2021).

4.1.1 Data from Previous Studies

The prices of food groups in grams were obtained from Abadie et al. (2016) and were originally reported in NOK per kg. To ensure consistency with other data sources, the prices were converted to NOK per 100 grams.

4.2 Description of Variables

For this thesis, five food groups have been chosen based on data availability for all parameters. These food groups include vegetables, fruits, and berries; whole grains; red meat; and fish. Additionally, the thesis incorporates four macronutrients: protein, fat, fibre, and energy requirements. A comprehensive description of each food group and macronutrient is presented below.

4.2.1 Food Groups/ Diet types

Vegetables, Fruits, and Berries

The recommendation for a healthy diet is to consume "five a day," which involves a daily intake of 500 grams of fruits and vegetables, equivalent to 5 portions a day, with each portion weighing approximately 100 grams (Directorate of Health, 2011). The Norwegian Directorate of Health recommends that vegetables should make up at least half of this daily intake, which is approximately 250 grams, while the remaining half should consist of fruits and berries (Directorate of Health, 2011). Vegetables, fruits, and berries provide essential sources of many macronutrients, and their consumption is known to help prevent cardiovascular disease. There is the flexibility to choose from a variety of options, including fresh, tinned, frozen, and heated vegetables, fruits, and berries (Directorate of Health, 2011).

Whole Grains

Whole grains are an essential component of a healthy diet and serve as the primary source of energy offering various health benefits such as reducing the risk of heart disease, type 2 diabetes, and overall mortality. The following guidelines are provided by the Norwegian Directorate of Health regarding the consumption of whole grains (Directorate of Health, 2011):

- Choose cereal products that are high in fibre and whole grains while being low in fat, sugar, and salt.

- Aim for a daily intake of whole grain foods that provide 70-90 grams of wholemeal flour or whole grains. This can be achieved through various combinations, such as:
- Four slices of bread that contain a significant portion of wholemeal flour, labelled as "ekstra grovt" (extra whole grain) in the Bread Scale symbol.
- A bowl of whole grain cereal along with two slices of extra whole grain bread.
- A bowl of oatmeal combined with one portion of whole grain pasta or whole grain rice.
- When shopping for bread and cereal products, look for the Keyhole and Bread Scale symbols as guides to identify products that meet these criteria.

Fish

Fish is highly recommended as part of a healthy diet due to its richness in omega-3 fatty acids. The global recommendation for omega-3 fatty acids from fish is set at a level of 2 grams per week (Willet et al., 2019). In terms of fish consumption, the general guideline is to "eat fish for dinner two to three times a week," with a suggested range of 300-450 grams per week (Willet et al., 2019). In the context of the diets being considered, an average of 375 grams of fish per week has been assumed in those diets where the dietary guidelines are deemed to be met (Directorate of Health, 2011).

Red Meat

Like the study by Mittenzwei (2020), we define red meat in this context as meat obtained from cattle. It includes meat from cattle, veal, sheep/lamb, and pork. The recommended intake of red meat is set at a maximum of 725 grams per week approximately less than 107grams per day, measured in raw weight Directorate of Health (2012*)*. The guidelines provided by the Norwegian Directorate of regarding red meat consumption Health (Directorate of Health, 2011) are as follows:

- Limit the amount of processed meat and red meat in the diet.

- Choose poultry, lean meat, and lean meat products that are low in salt.
- Restrict the consumption of processed meats that are smoked, salted, or preserved with nitrate or nitrite, such as bacon or salami.
- Limit the consumption of red meat and processed meat to less than 500 grams per week. This is equivalent to two to three dinners and a small amount of meat topping. Red meat includes meat from pigs, cattle, sheep, and goats.
- Preferably choose meat and meat products that carry the Keyhole label, indicating healthier options.

4.2.2 Macro Nutrients

Proteins: Proteins are essential macronutrients that play a crucial role in growth and overall health. The quality of proteins is determined by their amino acid content. While foods high in protein are beneficial for growth, it is important to consume proteins as part of a balanced meal alongside other nutrients to support optimal health (Gonera & Milford, 2018). Major sources of protein include meat, dairy products, fish, eggs, legumes, and nuts. These sources can be used to define various dietary patterns such as omnivore, vegetarian, pescatarian, or vegan. Additionally, there are individuals who follow flexitarian or meat-reducing diets, which include reduced consumption of meat (Gonera & Milford, 2018). Animal proteins are superior sources of protein compared to plant-based proteins. The quality of protein is determined by the presence of essential amino acids. High-quality protein sources are particularly important for infants and young children as proteins aid in cell replication. However, excessive protein intake has been linked to an increased risk of cancer (Willet et al., 2019). The Norwegian Directorate of Health recommends that protein should contribute to 10-20 percent of the total energy content in one's diet.

Fat

Fat is an important macronutrient that provides concentrated energy to the body. In addition to energy, dietary fats also supply essential fatty acids and fat-soluble vitamins. However, it is important to consume fats in moderation, as a high intake of fat has been associated with an increased risk of certain diseases, including cardiovascular diseases, certain cancers, obesity, and gallstones (Willet et al., 2019). The recommended contribution of fat to the total energy content in the diet is between 25-40 percent. Currently, the Norwegian diet consists of approximately 35 percent fat, which aligns well with the recommendations (Mittenzwei, 2020).

To maintain a healthy fat intake, the guidelines below have been recommended can be followed:

- Limit the consumption of dairy products high in saturated fat, such as full-cream milk, cream, fatty cheese, and butter.
- Choose low-fat dairy products that are low in salt and added sugar.
- Give preference to dairy products labelled with the Keyhole label, indicating healthier choices.
- Replace foods high in saturated fat with those containing more unsaturated fat. Soft margarine, spreads, liquid margarine, and cooking oils are better options compared to hard margarines and butter in terms of unsaturated fat content (Directorate of Health, 2012).

Energy Requirements

Energy expenditure is a crucial aspect of maintaining good health and is influenced by factors such as body weight, body composition, and physical activity levels. The energy requirement of individuals varies depending on factors such as growth in children, tissue deposition during pregnancy, and milk production during lactation (Nordic Council of Ministers, 2013). Energy expenditure is typically measured in kilojoules (kJ), where 1000 kJ is equivalent to 1 megajoule (MJ), and 1 kilocalorie (kcal) is equal to 4.184 kJ. In the Norkost 3 report, an average energy intake of 9,400 kJ per person per day was calculated (Directorate of Health, 2012*)*.

Fiber

Dietary fibre is an essential component of a healthy diet. It refers to the indigestible parts of plant foods that pass through the digestive system relatively intact. (Prosky, 2000). Fiber provides several health benefits, including promoting healthy digestion, preventing constipation, and reducing the risk of certain diseases (Ma et al., 2019). Whole grains, fruits, vegetables, legumes, nuts, and seeds are excellent sources of dietary fibre containing both soluble and insoluble fibre. Soluble fibre helps lower cholesterol levels and regulate blood sugar levels, while insoluble fibre adds bulk to the stool and supports regular bowel movements (Ma et al., 2019).

4.3 Methodology

4.3.1 The Model

Adopting the conventional framework of neoclassical consumer theory which assumes that a consumer chooses the consumption of *i* goods in quantities.

$$x = (x_1, \dots \dots \dots, i)$$

For a utility function:

$$U(x_1, \dots \dots \dots, x_i) \qquad (1)$$

With properties:

a) strictly increasing
b) strictly quasi-concave
c) twice differentiable utility function

This utility function is subject to a linear budget constraint.

$$p.x \leq B \qquad (2)$$

Where:

p = price vector

B= Budget

Following the assumption of Irz et al. (2015) an additional constraint is included of a consumer that operates under N additional linear constraints corresponding to N maximum nutrient intakes:

$$\sum_{i=1}^{N} a_i^n x_i \leq r_n \qquad \forall n = 1, \dots, N \qquad (3)$$

Equation 3 can assume a constant nutritional coefficient a_i^n for any food *I* and nutrient *n* or assume linearity between the diet types.

Menuier (2019) model disentangles equation (1) into the health and taste costs of the consumer, which is represented as

$$U(T(x), Q(x)) \qquad (4)$$

Here, *a*, *p*, and *x* are vectors of dimension *H*, and *M* and *R* are positive real numbers. *Q(x)* is the health in QALYs as a function of the diet, and *T(x)* represents its taste.

$$\max \quad U(T(x), Q(x)) \qquad (5)$$
$$\text{subject to } M - p.x \leq 0 \quad \text{and} \quad R - a.x \geq 0$$

The Lagrangian function of the model can be written as:

$$L(x, \lambda, \mu) = U(D(x)) + \lambda(M - p.x) + \mu(R - a.x)$$

The maximization problem gives us the uncompensated demand function:

x = *x (p, M, R)*

This represents the relationship between the prices of food group (*p*), the expenditure of the consumer on food, and the nutrient intake from the actual diet consumed.

For our study, we use DALYs (D) in place of QALYs (Q), we drop the taste variable and include a constant of DALYs (C_i). This brings the objective function to:

$$max \qquad -\sum_{i=1} U(D_i\, x_i - C_i) \qquad (6)$$

DALYs is an ideal measure because the measure factors both the years of life lost due to premature death and the years lived with disability. Constrained optimization of DALYs helps choose the best diet level to minimize the overall disease burden or health loss adjusted life years (Oslo Economics, 2020). and maximize the health benefits of healthy life years.

The idea to drop the taste cost was due to lack of data as this requires a survey to calculate the Willingness to Accept (WTP) or Willingness to Accept (WTA) among Norway's population the NDG.

Our model considers five diet types (i): whole grains, fish, vegetables, red meat, and fruits. It also considers four nutrient types: protein, fibre, kilojoules, and fat. Each diet type is assigned DALYs based on the associated risks factors stemming from diets low in whole grains, fish, vegetables, and fruits, as well as diet high in red meat all as a cause of non-communicable diseases like diabetes and cardiovascular diseases.

Constrained optimization is done for 3 different models. The first model is based on the intake values from the theoretical minimum risk level (TMREL) specified in the GBD. The TMREL is the intake level that gives the least burden, and it assumes that there is a linear dose-response relationship between changes in dietary factors and changes in the burden of disease. The second model minimizes DALYs based on the actual intake obtained from the Norkost 3 survey. In the final model, the diet is optimised based on the recommended intake from the NDG.

The objective functions are minimized subject to a budget constraint with a budget (B) and a nutrient constraint in equation (7) below.

$$subject\ to \quad \sum_{i=1} p_i\, x_i \ \leq B \quad and \quad \sum_{i=1}^{N} a_i^n\ x_i \geq r_n \qquad \forall n = 1, \dots, N \qquad (7)$$

The price of each diet is specified in Norwegian kroners per gram obtained from Abadie (2016) (Appendix 4). The required minimum nutrient (*r*) for each diet is based on the nutrient contents (*n*) available per 100grams of each diet type (*i*). This has been calculated (Appendix 1) with figures obtained from the Matvaretabelle. This ensures that the optimized diets meet the maximum nutritional requirements for meat and the minimum nutritional requirements for the others.

Bounds have also been set for the actual intake of each food item, representing the actual diets for males and females, respectively. These bounds restrict the maximum and minimum intake of each food item based on the kink points. By considering the observed intake values for each food item among males and females, the model aims to optimize their diets while adhering to the defined boundaries.

4.3.2 Choice of modelling program

The data was inputted and cleaned in excel. Analysis was carried out using gams studio version 1.4.1106. GAMS is a mathematical modelling tool that allows for the formulation and optimization of complex mathematical models. It also provides a user-friendly interface that allows for easy model development, debugging, and analysis (GAMS, 2023).

4.4 Impact on Norway's Agriculture

To assess how a change in diet can impact Norway's agriculture, coefficients have been obtained from personal communication. representing the land requirements in decares (daa) per feed type and meat production in kilograms or different livestock categories.

Table 5-1 Coefficients of livestock categories

Livestock Category	Fodder daa/animal	Coarse grain daa/animal	Meat production kg/animal
Dairy cow	16.382	3.204	263.308
Suckler cow	20.824	1.333	276.963
Sheep/goat	1.682	0.101	27.395
Pig		0.404	82.107
Poultry		0.009	1.412

Source: Personal communication

The coefficient Fodder daa/animal for dairy cow is 16.382daa. One dairy cow requires approximately 16.382 daa of land to grow fodder, 3.204 daa for coarse grains, and produces 263.308 kilograms of meat per animal.

A Suckler cow also requires approximately 20.824 daa of land for fodder, 1.333 daa for coarse grains, and produces 276.963 kilograms of meat per animal.

Sheep/goat requires approximately 1,682 daa of land for fodder, 0.101 daa for coarse grains, and produces 27,395 kilograms of meat per animal.

A pig requires approximately 0.404 daa of land for fodder and 82.107 kilograms of meat per animal. Finally, poultry requires approximately 0.01 daa of land for fodder, 1.412 daa for coarse grains.

5 Results and Discussion

This chapter presents the results of the study and engages in a detailed discussion of the findings. The key results address each research questions in a systematic manner. For the first research question, DALYs have been used to quantify the health impact of dietary risk factors. The results obtained have been used in the analysis of research question 2, where the impact on Norway's agriculture has been analysed.

5.1 Socioeconomic Health Benefits

Table 5-1 below shows the total utility of DALYs obtained from the linear optimization of three models for both males and for females. In model 1, the maximum health benefits (TMREL) have been compared to the current diet, Model 2 represents the health benefits/costs of the current diet, and Model 3 represents the health benefits/costs according to the NDG.

Table 5-1 Total Utility of DALYs

	Model 1 **Model with Maximum Health Benefits (compared to the current diet)**	Model 2 **Model with health benefits/costs of the current diet**	Model 3 **Model with health benefits/costs according to the dietary recommendations**
Male	202,447	167,324	197,463
Female	202,849	168,274	192,468

Source: Authors computation in GAMS

In Model 1, the total utility of DALYs is 202.447 for males and 202.849 for females. This indicates the maximum health benefits achieved in comparison to the TMREL.

In Model 2, the total utility of DALYs based on the cost of the current diet is 167.324 for males and 168,274 for females. This represents the health benefits/costs associated with the current diet.

In Model 3, the total utility of DALYs based on the health benefits/costs according to the dietary recommendations is 197,463.4093 for males and 192,468.8093 for females. This represents the health benefits/costs achieved by following the NDG.

5.2 Health benefits gained/lost from switching to the NDG:

To determine the health benefits of transitioning from the current diet to the dietary recommendation, we assess the difference between the total utility derived from the current diet and the total utility achieved by adhering to the Norwegian Dietary Guidelines (NDG). This comparison enables us to ascertain whether there is a net gain or loss in health outcomes resulting from the dietary shift. By comparing these two values, we gain valuable insights into the impact of dietary changes on overall health and well-being.

5.2.1 Health benefits gained/lost for male

$$Total\ Utility\ of\ Dalys\ for\ male\ \ in\ given\ the\ NDG\ diet$$

$$-\ Total\ Utility\ of\ Dalys\ for\ male\ given\ the\ current\ diet$$

$$197{,}463 - 167{,}324\ =\ 30,139\ utility\ of\ DALYs$$

The calculation compares the total utility of DALYs for males in Model 3, representing adherence to the Norwegian Dietary Guidelines (NDG), with the total utility of DALYs for males in Model 2, representing the current diet. The difference of 30,139 utils indicates the amount of DALYs that will be minimised, i.e., the health benefit that males can achieve by transitioning from the current diet (Model 2) to adhering to the NDG (Model 3). This positive difference suggests that following the NDG can lead to an improvement in overall health and well-being for males compared to their current dietary habits.

5.2.2 Health benefits gained/lost for female

$$Total\ Utility\ of\ Dalys\ for\ female\ \ in\ Model\ 3$$

$$- Total\ Utility\ of\ Dalys\ for\ female\ in\ Model\ 2$$

$$192{,}468 - 168{,}274\ =\ 24{,}194\ utils\ gained$$

Similarly, the calculation compares the total utility of DALYs for females in Model 3, representing adherence to the Norwegian Dietary Guidelines (NDG), with the total utility of DALYs for females in Model 2, representing the current diet. The difference of 24,194 utils indicates the gain in health benefit that females can achieve by switching from the current diet (Model 2) to the NDG (Model 3). It shows the overall DALYs that will be minimised i.e. The reduction in disease burden. This positive difference suggests that following the NDG can lead to an improvement in overall health and well-being for females compared to their current dietary habits.

5.3 Consequences for Norway's Agriculture

5.3.1 Consumption levels and marginal utility for each model

The table below presents food consumption levels and marginal utility of DALYs for the three diets (i.e., TMREL, current diet, and diet according to the Norwegian Dietary Guidelines). The Marginal Utility (MU) values represent the change in utility of DALYs associated with consuming an additional unit of a specific food item. A positive MU indicates consuming more of the diet is not harmful meaning it provides additional utility or benefits. Conversely, a negative MU implies more consumption is harmful as it decreases utility or has negative impacts.

A. Males

Table 5-1 Consumption levels and marginal utility for males for each model

	wgrain	fish	vegs	fruits	redmeat
Model 1					
Consumption Level (in grams)	125	109	300	400	14
Marginal Utility (in health benefits)	176	.	.	95	-86
Model 2					
Consumption Level (in grams)	70	79	154	168	53
Marginal Utility (in health benefits)	250	EPS	84	162	-98
Model 3					
Consumption Level (in grams)	90	54	250	250	14
Marginal Utility (in health benefits)	250	.	84	162	-98

Source: Authors computation in GAMS

B. Females

Table 5-2 Consumption levels and marginal utility for females for each model

	wgrain	fish	vegs	fruits	redmeat
	MODEL 1				
Consumption Level (in grams)	125	64	300	400	14
Marginal Utility (in health benefits)	176	.	.	95	-86
	MODEL 2				
Consumption Level (in grams)	52	56	155	189	33
Marginal Utility (in health benefits)	249.73	EPS	84.007	162	-98
	MODEL 3				
Consumption Level (in grams)	70	54	250	250	14
Marginal Utility (in health benefits)	250	.	840.07	162	-98

Source: Authors computation in GAMS

The consumption levels in A and B represent the quantities of specific food items consumed in each model. The food items listed in the table are whole grains (wgrain), fish, vegetables fruits, and red meat.

In model 1 for males, the consumption of red meat given the current diet (model 2) at 53 grams, shows a MU of -98. This implies that an additional 1gram consumption of red meat could lead to a decrease in health benefits by 98. Similarly for females.

The positive MU values for the consumption of fruit and vegetables imply an addition 1 gram consumption of this would bring about additional health benefit. Whole grains and Fish not do not necessarily add additional benefits or bring about losses.

5.3.3 Land area used based on the current diet

The observed consumption of red meat in model 1 varies for male and female, thus the average of both is found, to give *43/day*. The total male population in Norway, in the year 2011 Norkost 3 survey was conducted amounted to 2,479,849 and female population was 2, 473,240, this gives a total of 4,953,089. A year also equals 365 days.

A. Total consumption of the population given the observed diet

$$\text{Total consumption of the population given the observed diet} =$$

$$\text{Observed consumption of red meat x Adult population in Norway}$$

$$= 43g/day\ x\ 4{,}953{,}089$$

$$= 212{,}982{,}827\ g/day$$

$$Equivalent\ to\ 212.983\ kg/day\ and\ 77{,}738{,}855\ kg/year$$

The above calculates the total consumption of the population based on the observed consumption of red meat and the adult population in Norway. By multiplying the observed consumption (converted to average for both male and female) of red meat per day (33 + 53/2 = 43) by the adult population (*4,953,089*), the result is *212,982,827 g/day*. This is equivalent to *77,738,855 kg/year*

B. Number of Cows required based on the observed consumption

$$Total\ meat\ produced\ =\ kg\ meat\ from\ dairy\ cows\ +\ kg\ meat\ from\ suckler\ cows$$

$$263.30kg/animal\ +\ 256.96kg/animal\ =\ 540.271kg$$

$$Number\ of\ Cows\ required$$

$$=\ Total\ consumption\ of\ the\ population\ given\ the\ observed\ diet/yr$$

$$/\ Total\ meat\ produced$$

$$77{,}738{,}855kg/540.271kg\ =\ 143{,}888\ cows/year$$

Based on the observed consumption of red meat in Norway, approximately *143,888 cows* would be required to meet the total demand of meat. This estimation is obtained by dividing the total consumption of the population by the combined meat production from dairy cows and suckler cows (*540.271 kilograms per animal)*.

C. Feed required for both cows based on the observed diet

$$Fodder/daa\ (suckler\ cow + diary\ cow)\ =\ 16.382\ +\ 3.204$$

$$= 19.586\ daa\ per\ animal$$

$$Fodder\ required\ =\ \ 143{,}888\ cows\ x\ 19.586\ daa\ per\ cows$$

$$=\ 2{,}814{,}457.18\ daa\ of\ fodder/yr$$

$$Coarse\ grain\ for\ both\ cows\ =\ 20.824\ +\ 1.333$$

$$=\ 22.173\ daa\ per\ cow$$

$$Coarse\ grain\ required\ =\ \ 143{,}888\ cows\ x\ 22.173\ daa\ per\ cows$$

$$=\ 3{,}190{,}437.58\ daa\ of\ coarse\ grain/yr$$

$$Total\ area\ required\ based\ on\ the\ current\ diet\ =\ 3{,}190{,}437.58 daa$$

Based on the current diet and consumption patterns, the total area of land required to meet the feed demands for both dairy cow and suckler cow is estimated to be 6,004,894.76 daa/year. This includes 2,814.457.18 daa of land required for fodder and 3,190,437.58 daa of land required for coarse grain.

5.3.4 Land area used based on the NDG

The estimates provided here corresponds to the same dietary composition that maximizes health benefits as observed in Model 1.

A. Total consumption of the population given the NDG

$$=\ Required\ consumption\ of\ red\ meat\ x\ Adult\ population\ in\ Norway$$

$$=\ 14g/day\ x\ 4{,}953{,}089$$

$$= 69{,}343{,}256 g/day$$

$$= \frac{25{,}310{,}284{,}790g}{yr} \, equivalent \ to \ 25{,}310{,}284.79kg/year$$

B. **Number of Cows required based on the NDG**

$$Total \ meat \ produced$$
$$= \ Amount \ of \ meat \ from \ a \ dairy \ cow$$
$$+ \ Amount \ of \ meat \ from \ suckler \ cows$$

$$263.30kg/animal \ + \ 256.96kg/animal \ = \ 540.271kg$$

$$Total \ consumption \ of \ the \ population \ given \ the \ NDG \ / \ Total \ meat \ produced.$$

$$25{,}310{,}284.790kg/540.271kg \ = \ 46{,}847.39cows$$

Based on the observed consumption of red meat in Norway, approximately *46, 847 cows* would be required to meet the total demand of meat. This estimation is obtained by dividing the total consumption of the population ($25{,}310{,}289.790kg$ by the combined meat production from dairy cows and suckler cows (*540.271 kg per animal*).

C. Feed required based on the NDG

$$Fodder \ for \ both \ cow \ = \ 16.382 \ + \ 3.204$$

$$= 19.586 \ daa \ per \ animal$$

$$Fodder \ required \ = \ 46{,}847cows \ x \ 19.586 \ daa \ per \ cows$$

$$= \ 917{,}552.93 \ daa$$

$$Coarse \ grain \ for \ both \ cows \ = \ 20.824 \ + \ 1.333$$

$$= \ 22.173 \ daa \ per \ animal$$

$$Coarse\ grain\ required\ =\ 46{,}847\ x\ 22.173\ daa\ per\ cow$$

$$=\ 1{,}038{,}747.12\ daa$$

5.3.5 Land area gained/lost from switching to NDG

The calculation shows ‘holding all else constant’, higher demand for feed production, and land resources under the current diet scenario. The total area required to meet the demand for red meat based on the current diet is 3,190,437.58 daa, as calculated earlier. Subtracting the total area required to meet the demand for red meat based on the NDG, which is 1,038,747.12 daa, from the total area required to meet the demand for red meat based on the current diet gives us a difference of 2,151,690.46 daa. This figure shows the amount of land, in decares, that will be save for crop production if the population switches to the NDG.

6 Conclusion and Recommendations

6.1 Health Benefits

Building on the research conducted by Sælensminde et al. (2016), health benefits are quantified based on the transition to a diet with a lower risk of disease. The approach involves reducing the population's consumption of red meat to align with the dietary advice provided by the Norwegian Directorate while simultaneously increasing the intake of vegetables, nuts, and fruits/berries. The calculations in this study have established a connection between the estimation of socioeconomic benefits and the total utility of Disability Adjusted Life Years (DALYs) for the Norwegian population. This estimation was achieved by optimizing a linear programming function. The objective of has been to minimize the adverse effects of diseases and health conditions on the population while maximizing the potential for healthier and more productive lives.

6.2 Norway's Agriculture

Our study also analyzed the significance of dairy cows and suckler cows in red meat production. The reduction of either dairy cows or suckler cows can have an impact on freeing land area. Dairy cows are an example of joint supply as they not only produce meat, but also milk, which is widely recognized as a significant source of high-quality proteins with various nutritional, functional, and physiological benefits (Playne et al., 2003; Mohammadi & Mortazavian, 2011). Dairy cows, belonging to the Bos Taurus species, are specifically bred for their high milk production, which is utilized in the production of various dairy products (Feldhamer et al., 1999), suckler cows on the other hand, are primarily bred for beef production and contribute to a larger stock of beef (Morgan, 2023). Encouraging investments in dairy farming can be a viable strategy for Norway to enhance the production of dairy cattle. By promoting such investments, existing farmers can mitigate the potential impact of reduced meat demand while aligning with the NDG. Furthermore, if Norway were to adopt the dietary recommendations and experience excess meat production, there could be opportunities for exporting meat to other countries. This could serve as an avenue for economic growth and agricultural expansion, benefiting the country's agricultural sector and specifically farmers that may be affected by this impact.

6.3 Conclusion

The thesis aimed to investigate the potential health benefits to society that could arise from adopting the diet recommended by the NDG The findings of the study indicate that there are considerable health benefits associated with such a dietary shift. These health benefits may be experienced at some point in the future. It is important to emphasize the future benefits when encouraging individuals to eat healthily and adopt a healthy lifestyle, which is what measures like DALYs seek to achieve.

Research has consistently shown that high consumption of red meat, combined with a low intake of fruits and vegetables, is closely linked to the development of chronic diseases such as cardiovascular disease and diabetes, among others. While these chronic diseases may not have a definitive cure, they can be effectively managed. Some may fully recover and continue to lead a healthy life, while others may not experience the same level of improvement.

At present, the consumption of fruits and vegetables remains low in comparison to the intake of red meat. Changing dietary habits is a complex process, and humans are generally resistant to change. It will take time for individuals and society to fully transition to new dietary recommendations. However, as awareness and understanding of the health benefits increase, it is expected that more people will adopt the recommended diet over time.

In addition to the health benefits to society, the thesis also sought to assess how this dietary shift would impact Norway's agriculture. The findings indicate that reducing red meat consumption in Norway would lead to an increase in available land space for crop farming, especially fruits, and vegetables. It is important to note that significant changes in agriculture use do not occur instantaneously. The weather conditions and landscape of the country may not be highly supportive of crop production, but the use of advanced technology can play a crucial role in overcoming these challenges.

One area that scientists and researchers can focus on is reducing the fat content in the meat while maintaining the same level of protein and taste and reducing emission that comes from breeding cows. This can be achieved through various means, such as exploring different breeds of cows or implementing specific feeding and breeding practices. Like how unhealthy fat content has been extracted from milk, researchers could also investigate techniques to extract or reduce unhealthy fat content in red meat.

A major strength of this thesis lies in the integration of non-linear models that contain kinked points in a linear optimization framework. Also, the minimization of the DALYs utility function in assessing the health impact of dietary intake is a novel contribution to the field as previous research in this area has not extensively explored this methodology.

Future research should prioritize the use of larger and more representative samples, particularly when collecting data on actual diet intake. Additionally, it could also be valuable to employ impact assessment methods such as Difference in Difference, Randomised Control Trial, propensity score matching, etc. on policy reforms in the agricultural sector that might arise in the future because of dietary changes. It is important to examine how farmers can leverage these changes to their advantage.

6.4 Recommendations

1. Investment in agriculture technology and research

Agriculture plays a crucial role in determining nutrition outcomes, and it is important that this is prioritized to improve nutrition. One way this can be achieved is by incentivizing the sector

(Willett et al., 2019). According to them, prices alone does not drive dietary choices but other factors such as cultural habits and convenience play significant roles. Encouraging innovation in developing alternative, meatless food products can also provide consumers with more choices that align with a healthy diet. Researchers have begun the exploration of synthetic meat as an alternative to red meat, that is, meat made in the laboratory. The study by (Gustavsen and Mittenzwei, 2022) indicates limited market potential for synthetic meat, as around half of the respondents prefer traditionally farmed meat. However, it does not mean the complete elimination of farmed meat production in Norway, as there would still be a significant amount of meat production, potentially in conjunction with dairy farming. This could be an area that more research could be conducted to explore future demands.

2. Price as an instrument

Sælensminde et al. (2016) believes that, if there are increased prices or other measures implemented to limit red meat consumption, individuals are likely to substitute red meat with the closest alternatives. Some individuals may choose to shift towards consuming more fruits and vegetables, which are generally considered healthy. Ensuring that healthy diets from sustainable food systems are affordable is a crucial aspect. Farmers often face pressure from suppliers to produce large quantities of inexpensive commodities while consumers are also prioritizing low-cost food to allocate their budgets for other household needs (Willett et al., 2019). Key policies to address price volatility include eliminating market barriers across local regions or markets, which can help in creating a more stable pricing environment for food and enhance affordability and accessibility to healthy diets within sustainable food systems (Willett et al., 2019). Research conducted by Abadie et al. (2016) suggests that implementing higher value-added tax (VAT) rates on unhealthy foods can be more effective in reducing purchases among households that frequently purchase such items. Conversely, removing VAT on healthy foods may increase purchases among households that typically purchase fewer of these items.

A similar approach can be adopted to limit the import of red meat. Restricting the supply of red meat in the market to only domestically produced sources, can help stabilize prices while supporting the interests of local farmers. To support the farmers that may have been hit by the restriction:

3. Food labelling and consumer information

Galarraga et al. (2013) propose that clear and informative food labelling can empower consumers to make healthier choices. The Keyhole label in Norway is an example of such labelling that has been put in place. It is a voluntary Nordic food label that applies to various product groups meeting specific nutrition requirements. It has been used in Norway, Denmark, and Sweden since 2009 and can be found on bread, meat, and cheese. These requirements include higher dietary fibre and wholegrain content, as well as lower levels of saturated fat, salt, and sugar compared to similar food products. Even though they may not have the Keyhole label, fresh fish, fruits, berries, vegetables, and potatoes are considered natural Keyhole products.

Taking this even further, restaurants can be encouraged to offer completely healthy meals on their menu by providing incentives or recognition. This can be done through a special sign or label, like the Keyhole or Michelin star signs, indicating that they predominantly serve healthy food. In grocery shops, display signs or labels in shops indicating where the healthy meals or ingredients are located should be made visible. This makes it easier for consumers to identify and choose healthier options while shopping.

4. Reward frequent purchasers of fruits and vegetables

Food apps like Æ, Kiwi Pluss, etc., can reward individuals who regularly purchase fruits and vegetables. Accumulating points or rewards through these apps can lead to benefits such as insurance packages or special healthcare benefits related to specific health needs like diabetes or heart disease. If well implemented, these individuals who adhere to nutritional recommendations by can be offered preferential treatment or better access to insurance and healthcare services. By implementing these recommendations, individuals are motivated to make healthier food choices, and their efforts are recognized and rewarded, further encouraging them to maintain a healthy diet.

References

Abadie, L. M., Galarraga, I., Milford, A. B., & Gustavsen, G. W. (2016). Using food taxes and subsidies to achieve emission reduction targets in Norway. *Journal of Cleaner Production*, *134*, 280-297.

Anand, S., & Hanson, K. (1997). Disability-adjusted life years: a critical review. *Journal of health economics*, *16*(6), 685-702

Andreosso-O'Callaghan, B. (2003). *The economics of European agriculture*. Springer.

Augustovski, F., Colantonio, L. D., Galante, J., Bardach, A., Caporale, J. E., Zárate, V., ... & Kind, P. (2018). Measuring the benefits of healthcare: DALYs and QALYs–Does the choice of measure matter? A case study of two preventive interventions. *International journal of health policy and management*, *7*(2), 120.

Becker, W., Lyhne, N., Pedersen, A. N., Aro, A., Fogelholm, M., Phorsdottir, I., ... & Pedersen, J. I. (2004). Nordic Nutrition Recommendations 2004-integrating nutrition and physical activity. *Scandinavian Journal of Nutrition*, *48*(4), 178-187.

Bommier, A., & Stecklov, G. (2002). Defining health inequality: why Rawls succeeds where social welfare theory fails. *Journal of health economics*, *21*(3), 497-513.

Budsjettnemnda for jordbruket (2019). *Totalkalkylen forjordbruket. Jordbrukets totalregnskap 2017 og 2018 og budsjett 2019*. Registrerte og normaliserte tall. Oslo, juni 2019.

Chernichovsky, D., Spiegel, U., Zion, U. B., & Gradstein, M. (1997). Optimal consumer subsidies and income transfers for minimum nutritional requirements: A basic model. *Food and Nutrition Bulletin*, *18*(4), 1-9.

Cohen, D., & Flood, C. (2022). Health economics. In *Health Studies: An Introduction* (pp. 269-294). Singapore: Springer Singapore

Directorate of Health (2011). *Kostråd for å fremme folkehelsen og forebygge kroniske sykdommer*. Directorate of Health. Retrieved April 26, 2023, from https://www.Directorate of Health.no/rapporter/kostrad-for-a-fremme-folkehelsen-og-forebygge-kroniske-sykdommer-metodologi-og-vitenskapelig-kunnskapsgrunnlag

Directorate of Health. (2023a). *Utviklingen I Norsk Kosthold 2022 Matforsyningsstatistikk.*

Directorate of Health. (2023b). *Nordic Nutrition Recommendations 2022*. Helsedirektoratet. Retrieved April 24, 2023, from https://www.helsedirektoratet.no/english/nordic-nutrition-recommendations-2022

Dolan, P. (1998). The measurement of individual utility and social welfare. *Journal of health economics*, *17*(1), 39-52.

Dupuit, J. (1844). On the measurement of the utility of public works. *International Economic Papers*, *2*(1952), 83-110.

Elvik, R. (2005). Økonomisk verdsetting av liv og helse. TØI-rapport 743/2005. Institute of Transport Economics.

Feldhamer, G.A., L.C. Drickamer, S.H. Vessey, J.F. Merritt.1999. Mammalogy*: Adaptation, Diversity, Ecology*. McGraw-Hill, Boston, Massachusetts, USA.Sælensminde, K., Johansson, L., & Helleve, A. (2016). Samfunnsgevinster av å følge Helsedirektoratets kostråd. *Oslo: Helsedirektoratet*.

Flaten, O., & Hisano, S. (2007). Food security policy in a food importing country: The case of Norway. *Nougyou to Keizai (Agriculture and Economy)*, *73*(8), 129-136..Gale, F., Hansen, J., & Jewison, M. (2015). *China's Growing Demand for Agricultural Imports*. www.ers.usda.gov

Fogelholm, M. (2013). New Nordic nutrition recommendations are here. *Food & nutrition research*, *57*(1), 22903.

Friel, S., Schram, A., & Townsend, B. (2020). The nexus between international trade, food systems, malnutrition and climate change. Nature Food, 1(1), 51-58.

Gonera, A., & Milford, A. B. (2018). The plant protein trend in Norway-Market overview and future perspectives. Nofima rapportserie.

Gustavsen, G. W., & Rickertsen, K. (2013). Adjusting VAT rates to promote healthier diets in Norway: A censored quantile regression approach. *Food Policy, 42,* 88-95

Gustavsen, G. W., & Mittenzwei, K. (2022). Potential demand for synthetic meat. *Proceedings in Food System Dynamics*, 44-52.

Gyles, C., Carlberg, J., Gustafson, J., Davlut, D., & Jones, P. H. (2010). Economic valuation of the potential health benefits from foods enriched with plant sterols in Canada. *Food & Nutrition Research*, *54*(1), 5113.

Hadjikakou, M., & Paraskevas, A. (2020). The environmental and health impacts of transitioning to plant-based diets: a review of the evidence for prospective policy-making. *European Journal of Public Health, 30*(Supplement_5), ckaa165-018. doi:10.1093/eurpub/ckaa165-018

Institute for Health Metrics and Evaluation (IHME) (2021). GBD 2019 Dietary Risk Collaborators. Health effects of dietary risks in 195 countries, 1990-2019: *a systematic analysis for the Global Burden of Disease Study 2019*. Seattle, WA: IHME

Irz, X., Leroy, P., Réquillart, V., & Soler, L. G. (2015). Economic assessment of nutritional recommendations. *Journal of health economics*, *39*, 188-210.

Janowska-Miasik, E., Waśkiewicz, A., Witkowska, A. M., Drygas, W., Markhus, M. W., Zujko, M. E., & Kjellevold, M. (2021). Diet quality in the population of Norway and Poland: Differences in the availability and consumption of food considering national nutrition guidelines and food market. *BMC public health*, *21*(1), 1-13.

Karlsson, M., & Hovelsrud, G. K. (2021). “Everyone comes with their own shade of green”: Negotiating the meaning of transformation in Norway's agriculture and fisheries sectors. *Journal of Rural Studies*, *81*, 259-268.

Knutsen, H., (2020). *Norwegian Agriculture Status and Trends 2019*. NIBIO Brage. Retrieved April 26, 2023, from https://nibio.brage.unit.no/nibio-xmlui/handle/11250/2643268

Lancaster, K. J. (1966). A new approach to consumer theory. *Journal of political economy*, *74*(2), 132-157.

Levin, J., & Milgrom, P. (2004). Introduction to choice theory. *Available from internet: http://web. stanford. edu/~ jdlevin/Econ*, *20202*.

Ma, W., Nguyen, L. H., Song, M., Jovani, M., Liu, P. H., Cao, Y., ... & Chan, A. T. (2019). Intake of dietary fibre, fruits, and vegetables, and risk of diverticulitis. *The American journal of gastroenterology*, *114*(9), 1531.

McKenna, M. T., Michaud, C. M., Murray, C. J., & Marks, J. S. (2005). Assessing the burden of disease in the United States using disability-adjusted life years. *American journal of preventive medicine*, *28*(5), 415-423.

Meunier, G. (2019). Economic assessment of nutritional recommendations: A comment.

Journal of health economics, *65*, 43-47. https://doi.org/10.1016/j.jhealeco.2019.03.003

Mittenzwei, K., Walland, F., Milford, A. B., & Grønlund, A. (2020). Klimakur 2030. Overgang fra rødt kjøtt til vegetabilsk og fisk. *79*. https://nibio.brage.unit.no/nibio-xmlui/handle/11250/2638457

Mohammadi R, Mortazavian AM. Review Article: Technological aspects of prebiotics in probiotic fermented milks. *Food Rev. Int.* . 2011;27:192–212

Morgan, C., Stewart, K., & Vickers, M. (2023). Better Returns: Feeding Suckler cows and calves for better return.AHDB Beef & Lamb. https://projectblue.blob.core.windows.net/media/Default/Beef%20&%20Lamb/FeedingSucklerCowsAndCalves2533_190311_WEB.pdf

Murray, C. J. (1994). Quantifying the burden of disease: the technical basis for disability-adjusted life years. *Bulletin of the World health Organization*, *72*(3), 429.

Murray, C. J., & Acharya, A. K. (1997). Understanding dalys. *Journal of health economics*, *16*(6), 703-730.

Ng, Y., 1983. Welfare Economics: Introduction and Development of Basic Concepts. MacMillan

Nordic Council of Ministers (2013). *Nordic Nutrition Recommendations 2012*. Nordic Council of Ministers.

Norwegian Food Safety Authority (2022). *Matvaretabellen 2022 (Food Table 2022).* Retrieved from https://www.matvaretabellen.no/

OECD (2021) Agricultural Policy Monitoring and Evaluation 2022. (2022). OECD. https://doi.org/10.1787/7f4542bf-en

Oslo Economics. (2020). Gjennomgang av de samfunnsøkonomiske kostnadene i kostholdstiltaket i Klimakur 2030. Rapport utarbeidet av Oslo Economics på oppdrag fra Matprat og Animalia, 30. mai 2020.

Playne M, Bennett L, Smithers G. Functional dairy foods and ingredients. *Aust. J. Dairy Technol.* . 2003;58:242–64.

Regjeringen. (2017). *Norwegian National Action Plan for a Healthier Diet – an outline. Healthy diet, meal enjoyment and good health for everyone!* Regjeringen.no. Retrieved May 1, 2023, from https://www.regjeringen.no/contentassets/fab53cd681b247bfa8c03a3767c75e66/norwegian_national_action_plan_for_a_healthier_diet_an_outline.pdf

Sassi, F. (2006). Calculating QALYs, comparing QALY and DALY calculations. *Health policy and planning*, *21*(5), 402-408.

Smith, A. (1776). *An inquiry into the nature and causes of the wealth of nations*. In R. H. Campbell & A. S. Skinner (Ed.). Oxford: Oxford

Sælensminde, K., Johansson, L., & Helleve, A. (2016). Samfunnsgevinster av å følge Helsedirektoratets kostråd. *Oslo: Directorate of Health*.

Ueland, Ø., Rødbotten, R., & Varela, P. (2022). Meat consumption and consumer attitudes–A Norwegian perspective. *Meat Science*, *192*, 108920

Varian, H. R. (2014). Microeconomics (2nd ed.). New York, NY: W. W. Norton & Company

Walras, L. (1874). Éléments d'économie politique pure, ou Théorie de la richesse sociale. Lausanne: Corbaz.

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., ... & Murray, C. J. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The lancet*, *393*(10170), 447-492.

Appendices

Appendix 1: Macronutrients obtained from recommended and observed diets. (Source: Own calculations)

Macro Nutrients	**Male**		**Female**	
	Recommended	Observed	Recommended	Observed
Whole Grain (Wheat Grain)				
Protein	11,7	9,1	9,1	7,02
Fiber	10,8	8,4	8,4	6,48
KJ	1197,9	931,7	931,7	718,74
Kcal	283,5	220,5	220,5	170,1
Saturated fat	0,27	0,21	0,21	0,162
Fish (Norwegian Salmon uncooked)				
Protein	10,746	12,736	10,746	8,756
Fiber	0	0	0	0
KJ	500,58	593,28	500,58	407,88
Kcal	120,42	142,72	120,42	98,12
Saturated fat	1,242	1,472	1,242	1,012
Vegetable (Carrot)				
Protein	1,75	0,448	1,75	0,448
Fiber	7,5	1,92	7,5	1,92
KJ	380	97,28	380	97,28
Kcal	90	23,04	90	23,04
Saturated fat	0	0	0	0
Fruits (Strawberry)				
Protein	1,045	0,32	1,16	0,32
Fiber	4,18	1,28	4,64	1,28
KJ	300,96	92,16	334,08	92,16
Kcal	71,06	21,76	78,88	21,76
Saturated fat	0	0	0	0
Red Meat (Cattle)				
Protein	23,54	32,12	23,54	19,58
Fiber	0	0	0	0
KJ	587,43	801,54	587,43	488,61
Kcal	140,17	191,26	140,17	116,59
Saturated fat	2,354	3,212	2,354	1,958

Appendix 2: Recommended and Observed intake of diet based on the NDG (Source: Norkost3 survey)

Food Group	Male		Female	
	Recommended	Observed	Recommended	Observed
Whole grain	90	70	70	54
Fish	54	64	54	44
Veg	250	64	250	64
Fruit	209	64	232	64
Redmeat	Less than or equal to 107	146	Less than or equal to 107	89

Appendix 3: Table on Disability adjusted Life Years (DALYs). (Source: IHME, 2021)

Food Group	Male	Female
Whole grain	583.29	387.15
Fish	69.26	39.73
Veg	155.74	98.82
Fruit	157.46	129.24
Redmeat	358.40	302.98

(Source: IHME, 2021)

Appendix 4: Price of Recommended diet per 100grams (Source, Abadie et al., 2016)

Food Group	Price NOK/g
Whole grain	4.2
Fish	9.3
Veg	3.4
Fruit	2.7
Redmeat	8.4

Norges miljø- og biovitenskapelige universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

Postboks 5003
NO-1432 Ås
Norway